

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A method of operating a charge pump, said method comprising:

operating a first-phase circuit of said charge pump to produce an output voltage at an output terminal;

operating a second phase circuit of said charge pump to produce an output voltage at said output terminal;

said first and second phase circuit being operated out of phase with one another; and

transferring charge between a driving side of a bootstrap capacitor of said first phase circuit and a driving side of a bootstrap capacitor of said second phase circuit during said operation.

2. A method of operating a charge pump as defined in claim 1, wherein said first and second phase circuits of said charge pump are operated 180 degrees out of phase with each other.

3. A method as defined in claim 1 wherein said first and second phase circuits further comprise respective first and second bootstrap capacitors, said transferred charge being transferred between said bootstrap capacitors.

4. A method as defined in claim 3 wherein said transferring of charge takes place between driving sides of said first and second capacitors.

5. A method as defined in claim 4, wherein said driving sides are switchingly connected together by a switching device having a control input, and wherein said method further comprises applying a control signal to said control input to cause said switching device to become electrically conductive.

6. A method of operating a charge pump having first and second bootstrap capacitors which are used to supply a pumped output voltage at an output terminal, said method comprising:

charging a driving side of said first bootstrap capacitor to a first electrical potential;

discharging a driving side of said second bootstrap capacitor to a second electrical potential;

transferring a charge from said driving side of said first bootstrap capacitor to said driving side of said second bootstrap capacitor to charge said driving side of said second bootstrap capacitor to a third electrical potential; and

charging said driving side of said second bootstrap capacitor from said third

electrical potential to said first electrical potential.

7. A method of operating a charge pump as defined in claim 6, wherein said driving side of said first bootstrap capacitor is operated out of phase with said driving side of said second bootstrap capacitor.

8. A method of operating a charge pump as defined in claim 6, wherein said charge pump has third and fourth bootstrap capacitors, further comprising:

operating said first, second, third, and fourth bootstrap capacitors out of phase with one another so as to define four separate operational phases.

9. A method of operating a multi-phase charge pump comprising:  
transferring charge from a first bootstrap capacitor of a first phase circuit to a second bootstrap capacitor of a second phase circuit so as to elevate a voltage across said second bootstrap capacitor; and

further elevating said voltage across said second bootstrap capacitor by transferring charge from a power supply to said second bootstrap capacitor.

10. A method of increasing electrical voltage on a capacitor terminal comprising:

connecting a first plate of a first capacitor to a source of a first potential;

connecting a second plate of said first capacitor to a source of a second potential, said second potential being different from said first potential, whereby said second plate assumes said second potential;

disconnecting said first and second plates from said respective sources and connecting said first plate to said source of said second potential, whereby said second plate assumes a third potential;

extracting an electrical charge from said second plate at said third potential;

connecting a third plate of a second capacitor to said source of said first potential;

connecting a fourth plate of said second capacitor to said source of said second potential, whereby said fourth plate assumes said second potential;

disconnecting said third and fourth plates from said respective sources and connecting said first plate of said first capacitor to said third plate of said second capacitor, whereby said third plate assumes a fourth potential, said fourth potential intermediate said first and second potentials;

disconnecting said first plate from said third plate; and

connecting said third plate to said source of said second potential, whereby said fourth plate assumes said third potential.

11. A method of increasing electrical voltage comprising:

connecting a first plate of a first capacitor to a source of a first potential;  
connecting a second plate of said first capacitor to a source of a second potential, said second potential being higher than said first potential, whereby said second plate assumes said second potential;

connecting said first plate to said source of said second potential, whereby said second plate assumes a third potential higher than said second potential;

connecting a third plate of a second capacitor to said source of said first potential;

connecting a fourth plate of said second capacitor to said source of said second potential, whereby said fourth plate assumes said second potential;

connecting said first plate of said first capacitor to said third plate of said second capacitor, whereby said third plate assumes a fourth potential, said fourth potential intermediate said first and second potentials; and

connecting said third plate to said source of said second potential, whereby said fourth plate assumes said third potential.

12. A method of operating a charge pump circuit comprising:

repeatedly transferring a charge between first and second bootstrap capacitors of respective first and second charge pump circuits; and

producing an output voltage that is elevated with respect to an input voltage in

response to said repeated transfers.

13. A method as defined in claim 12, wherein said first and second charge pump circuits have respective first and second outputs, said first and second outputs being mutually connected to an electrical load.

14. A method as defined in claim 13, further comprising:  
operating said first and second charge pumps out of phase with one another.

15. A method as defined in claim 14, wherein said operating said first and second charge pumps out of phase with one another further comprises operating said charge pumps 180 degrees out of phase with one another.

16. A method as defined in claim 13, further comprising operating said first capacitor in a voltage range between a first voltage and a second voltage;

operating said second capacitor in a voltage range between said first voltage and said second voltage;

beginning to transfer charge from said first capacitor to said second capacitor when said first capacitor is at said first voltage and said second capacitor is at said second voltage; and

continuing to transfer charge from said first capacitor to said second capacitor until a voltage on said first capacitor is substantially equal to a voltage on said second capacitor.

17. A charge pump circuit comprising:

four phase circuits, each of said phase circuits including a primary phase circuit and a respective ancillary phase circuit, said respective ancillary phase circuits each serving to control a transistor of said respective primary phase circuit, said four primary phase circuits operated out of phase with one another.

18. A charge pump circuit as defined in claim 17, wherein said respective ancillary phase circuits each operate out of phase with one another.

19. A method of operating a charge pump having two capacitors comprising:  
charging a first capacitor during a first time period;  
discharging said first capacitor into a second capacitor during a second time period;  
further charging said second capacitor during a third time period; and  
discharging said second capacitor into said first capacitor during a fourth time period.

20. A multi-phase charge pump comprising:

a plurality of single phase charge pump circuits each including a respective bootstrap capacitor, at least two of said plurality operated in offset phase from one another; and

a charge transfer circuit adapted to transfer charge between said at least two single phase charge pump circuits.

21. A multi-phase charge pump as defined in claim 20, wherein said plurality of single phase charge pump circuits includes at least a first charge pump circuit and a second charge pump circuit, and said first charge pump circuit operating  $180^\circ$  out of a phase with respect to said second charge pump circuit, and said plurality of single phase charge pump circuits are mutually connected at a respective plurality of outputs.

22. A multiphase charge pump as defined in claim 20, wherein said plurality of single phase charge pump circuits includes first, second, third, and fourth charge pump circuits operating at respective phase angles of  $0^\circ$ ,  $90^\circ$ ,  $180^\circ$ , and  $270^\circ$ .

23. A charge pump circuit comprising:

a first charge pump phase circuit including a first bootstrap capacitor

containing stored energy;

a second charge pump phase circuit including a second bootstrap capacitor;

and

a circuit for transferring energy from said first bootstrap capacitor to said second bootstrap capacitor to enable said second bootstrap capacitor to utilize energy previously stored in said first bootstrap capacitor to elevate a potential on said second bootstrap capacitor.